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AN INVESTIGATION OF THE

POLLUTIONAL CHARACTERISTICS OF

RUNOFF FROM TWO FEEDLOTS

AN INVESTIGATION OF THE POLLUTIONAL CHARACTERISTICS OF RUNOFF FROM TWO FEEDLOTS

BY

PAUL E. THORMODSGARD

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Civil Engineering, South Dakota
State University

1970

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AN INVESTIGATION OF THE

POLLUTIONAL CHARACTERISTICS OF

RUNOFF FROM TWO FEEDLOTS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor Date

Head, Date
Civil Engineering Department

ACKNOWLEDGMENTS

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INTRODUCTION

American agriculture has advanced considerably in recent years. These unprecedented advances result primarily from recent developments which have occurred in agricultural science and technology. In particular, new techniques in animal production have been developed. During the first half of the twentieth century, the production of livestock had been typically conducted on a small scale. A large number of independent operators produced livestock with each operation producing relatively few animals. Recent trends, however, have been toward the feeding of more animals on fewer feedlots (1).

The concentrating of large numbers of animals has undoubtedly increased the efficiency of animal production in certain parts of the country. But the confinement of animals has also resulted in the concentration of their wastes. Because waste management has become a major operational problem, improved methods of handling, treatment, and disposal of animal wastes must be developed (2).

The need for runoff control facilities at animal feeding operations has just been recognized in the past few years (3). Concern has been expressed by water pollution control officials in regard to the pollution potential of animal wastes. As a result, regulations to reduce pollution from feedlot sources are being formulated. The major cattle-producing states of Texas, Kansas, Nebraska, Colorado, and Iowa have already established regulations for feedlot pollution control (4). South Dakota and several additional states are in the process of drawing up similar regulations. Unfortunately, these regulations are, in some cases, being formulated with limited evidence of the pollution resulting directly from animal feeding operations. A recent study conducted in the Big Sioux River basin in South Dakota indicated that feedlots contribute a very small portion of the BOD load normally present in the river (5).

Past research has been concerned primarily with feedlot pollution resulting from rainfall. Information in the literature regarding the influence of spring runoff from snowmelt was not found.

The general objective of this investigation was to explore the pollutional characteristics of runoff from two feedlots in eastern South Dakota. The specific objectives of the investigation were:

1) To determine the quantity and quality of feedlot runoff from the Animal Nutrition unit and the Dairy Research and Production unit at South Dakota State University.
2) To investigate the spring feedlot runoff resulting from snowmelt as well as the runoff produced by spring rainfall.
3) To determine the pollutional characteristics attributable to the suspended matter in the feedlot runoff

in order to assess the effectiveness of settling in reducing the waste concentrations in feedlot runoff.

LITERATURE REVIEW

Animal Production Trends

Livestock production in the United States is a major industry. During the past twenty years, the population of the United States has been increasing at an average annual rate of three million people per year (1). The beef cattle industry, especially, has advanced in recent years. Fed cattle marketings are being increased annually by approximately 6.5 per cent on a nation-wide basis (3). This can be attributed not only to an increasing population but also to an increase in the per capita consumption of beef. From 1950-1966, the per capita consumption of all meats increased by about 15 per cent; however, the per capita consumption of beef increased by 34 per cent during this same period (2).

In the beef industry the national trend has been toward the production of larger numbers of beef cattle on fewer feedlots. One feedlot in Colorado, for example, finishes about 250,000 steers per year (1). Dague et al. (3) summarized fed cattle marketings for the leading cattle-producing states in 1967. These production data are presented in Table 1.

According to Table 1, South Dakota ranked seventh in fed cattle marketings for the Midwestern states in 1967. Foley (5) tabulated

Table 1. Fed Cattle Marketings from the Leading Cattle Producing States during 1967 (3).

State	Number of Cattle Marketed
7 Leading States	
Iowa	4,057,000
Nebraska	3,066,000
California	2,049,000
Texas	1,654,000
Colorado	1,330,000
Kansas	1,321,000
Illinois	1,279,000
Total	14,756,000
12 Leading Midwestern States	
Iowa	4,057,000
Nebraska	3,066,000
Kansas	1,321,000
Illinois	1,279,000
Minnesota	869,000
Missouri	690,000
South Dakota	618,000
Indiana	496,000
Ohio	442,000
Michigan	240,000
Wisconsin	206,000
North Dakota	139,000
Total	13,423,000

the size and number of cattle feedlots in South Dakota. The information was gathered through a survey conducted by county agents in February, 1967. This distribution is shown in Table 2.

Table 2. Size and Number of Cattle Feedlots in South Dakota (5).

Number of Animals per Lot	Number of Lots
less than 100	12,109
100-300	2,269
300-500	596
500-1000	202
greater than 1000	101

Problems Associated with Feedlot Wastes

Problems associated with animal wastes can be attributed primarily to the production of livestock in confined areas. The collection, treatment, and disposal of animal wastes present significant waste management problems. In past years the problems were less critical because livestock were allowed to graze in pastures. Wastes which were produced were not concentrated, and decomposition occurred rapidly (6).

The uncontrolled runoff from animal feeding operations has the potential for creating serious water pollution problems (2)(3)(7)(8) (9). It has been estimated that over 80 percent of the fish killed in Kansas from 1964-1967 resulted from manure, silo, and feedlot drainage (9). In 1964 agricultural operations were blamed for eight per cent of the total fish kill in the United States (10).

Because of the high concentration of wastes at animal feeding operations, feedlots may provide a prime source of wastes for contamination of ground water. In addition, feedlot runoff may serve as a vehicle for the transmission of waterborne disease. However, documentation of actual cases is rare (2).

Management of Feedlot Wastes

The management of animal wastes has developed into a major operational problem. Unfortunately, there is no single waste disposal technique which can be implemented to satisfactorily handle animal waste problems for all feedlots. The optimum disposal method for a specific feedlot operation depends upon many factors. Major factors include availability of land, nearness to population centers, treatment required, and economy of the method.

The land is probably the most logical site for the disposal of animal wastes. Field spreading of solid manure has been and still is an acceptable method of disposal where sufficient land area exists. By returning the wastes to the soil, utilization of the waste nutrients may be obtained. Precautions must be taken to prevent contamination of receiving streams or development of an odor nuisance (1). Spreading the solid manure on the land is usually the lowest cost manure handling system; however, labor requirements are probably the highest of any system available (11).

A similar waste disposal technique involves the liquefaction of the feedlot wastes prior to disposal. Two techniques can be utilized in disposing of the liquid manure. One system involves pumping the liquid from a storage holding tank through an irrigation system onto the crop land. The other system, a rather recent innovation, is the plow-furrow method in which the liquid manure is plowed under during discharge onto the land (1). Its major feature is that the odor nuisance is negligible and, as such, is acceptable in highly urbanized areas. A disadvantage of any liquid disposal system is the characteristically high initial investment. Necessary equipment include a leak-proof holding tank, a pumping system, and facilities for final disposal of the liquid waste (11).

Another possible approach to the waste management problem involves the treatment of feedlot wastes in anaerobic lagoons. Anaerobic lagoon treatment of feedlot wastes offers considerable potential for waste treatment, but the method does have certain limitations. Lagoons provide excellent conditions for sedimentation of water-carried manure solids. The solids may be carried into a lagoon by flushing the feedlot with water or by feedlot runoff resulting from precipitation. At some operations, the manure accumulations are simply scraped into lagoons. The degree of treatment provided by an anaerobic lagoon may be substantial, and considerable destruction and stabilization of organic matter can be obtained. Because only a small surface area is required for an anaerobic lagoon, land costs should not be prohibitive. Another favorable condition is that the volume of effluent from an anaerobic lagoon is quite small. This is a desirable condition from a pollution control standpoint (12).

There are, however, certain limitations to anaerobic lagoon treatment. Even though a considerable degree of treatment can be obtained in an anaerobic lagoon, the lagoon effluent will contain high concentrations of nitrogen, solids, and oxygen-demanding materials. As a result, the effluent could pollute a receiving body of water (12). One problem which may arise in lagoons is that of infiltration loss and contamination of ground water. Consequently, it is essential that the bottom of a lagoon be watertight. Excessive odors are another problem which may be encountered with an anaerobic lagoon (8). In view of these limitations, anaerobic lagoons do not appear to be the complete answer to feedlot waste control. However, they may be a useful component when used in combination with subsequent units which will treat the anaerobic lagoon effluent (12).

Aerobic treatment of animal wastes may be feasible when sufficient oxygen can be supplied for stabilization. Oxidation ponds, aerated lagoons, and oxidation ditches are aerobic treatment processes which have attracted attention as possible treatment methods for animal wastes. Because of the tremendous quantities of manure that are produced in livestock feeding operations, the surface area and water requirements of an oxidation pond may be prohibitive. Oxidation ditches which have been used in the United States were primarily for odor control. Aerobic treatment devices can be used effectively in stabilizing the effluent from anaerobic lagoons (2).

Recent waste management thinking has been directed toward systems which remove objectionable odors or which utilize its nutritive value (13). Composting is a waste treatment process which removes the objectionable odors from feedlot wastes. The composting process converts the organic wastes into a relatively stable humus by aerobic, thermophilic decomposition. Mixing and aeration of the wastes are needed to provide optimum conditions for decomposition. The final product which is quite odor-free and stable has in some cases been sold as a soil conditioner. Coprophagy is a waste management technique which involves the feeding of animal manure to animals. The main advantage is that the nutritional value of the waste can be utilized. In one case, pullets and laying hens satisfactorily subsisted on a cattle manure diet (1).

Pollution Potential of Feedlot Runoff

Because of the concern expressed by the American people over the degradation of our waters, the Water Quality Act of 1965 was passed. Stream water quality standards were subsequently established. As a result, industries and municipalities were required to treat their wastes. In recent years the runoff from animal feeding operations has been recognized as a potential source of water pollution. Because the water pollution problem associated with feedlot wastes is basically a drainage problem, the feedlot wastes rarely represent a serious water pollution problem until they actually enter a receiving stream (8).

Before runoff from a feedlot can develop, there must be sufficient moisture for runoff to occur. In northern climates, runoff may result from rainfall or snowmelt. In either case, the runoff would flow to a receiving stream on an intermittent basis. This intermittent nature of runoff has advantages and disadvantages. An advantage is that only a small portion of the total waste accumulated on the lot is carried away by the runoff, and during these periods, considerable dilution of the wastes may be provided by the stream. The intermittent nature of feedlot runoff has a distinct disadvantage in that a highly concentrated waste may flow to a receiving stream in a rather short period of time. This phenomenon is typically referred to as a "shock load" on the receiving stream. The effect of the shock load depends upon the total waste load received, the time period in which it is received, and upon the nature of the stream (3).

Miner and Smith (7) state that for a feedlot under a given set of conditions, it is difficult to quantitatively predict the degree of pollution to be expected. They listed the following factors as being significant in evaluating the pollution potential of a feedlot: size of the lot; cleanliness of the lot when runoff occurs; general topography of the area; location of the lot with respect to receiving waters, the amount, intensity, and pattern of rainfall within the drainage basin; the size of the receiving stream; and the pollution control measures in use. Factors which seem less important are the quantity and strength of the wastes defecated by the animal. With regard to lot cleanliness, they report that after two weeks of waste accumulation, the strength of the runoff would not be significantly altered by additional waste accumulations (10).

The potential water pollution problems attributable to animal wastes are often discussed in terms of population equivalents. The population equivalent of an animal waste equates the total animal waste production to an equivalent human waste production of 0.17 pounds of BOD per capita per day. Matthew (14) reported that in 1967 the total livestock waste load in South Dakota could be equal to the untreated wastes of 18,150,000 people. The population of South Dakota at that time was less than 700,000 people. As a result, livestock in South Dakota apparently produced 25 times as much waste as was produced by the people of South Dakota. Matthew's calculations were based upon the following assumptions: one beef cow produces waste equivalent to 3.5 humans; one hog is equivalent to 0.9 humans; one sheep is equivalent to 0.31 humans; and one hen is equivalent to 0.17 humans.

Matthew was careful to point out, however, that not all livestock wastes are carried into receiving waters. The size of the total animal waste load does suggest that animal wastes must be considered in maintaining water quality in South Dakota (14).

Nature of Pollution from Feedlot Runoff

Degradation of receiving waters resulting from feedlot runoff can occur in various forms. The degradation may be in the form of increased nutrient concentrations which promote excessive aquatic growths or of depleted oxygen levels. Tastes and odors which may be imparted to the receiving water would reduce the value of the

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water not only as a domestic water source but also as a recreational site. Furthermore, feedlot runoff may serve as a vehicle for disease transmission (8).

The concentrations of oxygen-demanding material in feedlot runoff can be high. Miner et al. reported chemical oxygen demand (COD) concentrations ranging from 3,000 to 11,000 milligrams per liter (mg/1) and that the greatest waste concentrations were obtained during warm weather, during periods of low intensity rainfall, and when the manure had been soaked with water. In addition, they stated that runoff from a concrete surfaced lot would be more heavily polluted than the runoff from a nonsurfaced lot under similar conditions (15).

Oxygen depletions in streams resulting from feedlot wastes have accounted for a number of fish kills throughout the country. Kansas, especially, has attributed a high number of fish kills to animal wastes. This should not suggest that fish kills from animal wastes are unique to Kansas, but rather that their pollution control officials recognize feedlot runoff as being a potential pollutant (16).

The inorganic pollution resulting from feedlot runoff can usually be attributed to the effects of nitrogen and phosphorus on a receiving body of water. A major problem which develops is the increased growth of algae and other aquatic plant species. An estimate of the nutrient contributions from various sources has been made and is presented in Table 3. These data indicate that agricultural runoff and animal wastes are important sources of nitrogen and phosphorus (17).

Table 3. Estimate of Nutrient Contributions from Various Sources in the United States (17).

Source	Nitrogen 1,000,000 lb/year	Phosphorus 1,000,000 lb/year
Domestic waste	1,100-1,600	200-500
Industrial waste	1,000	**
Rural runoff:		
Agricultural land	1,500-15,000	120-1,200
Nonagricultural land	400-1,900	120-750
Farm animal waste	1,000	**
Urban runoff	110-1,100	11-170
Rainfall*	30-590	3-9

* Considers rainfall contributed directly to water surface.
** Insufficient data available to make estimate.

The ammonia and organic forms of nitrogen are frequently found in high concentrations in feedlot runoff. When the feedlot runoff enters a receiving stream, the ammonia and organic nitrogen are oxidized, and consequently, an oxygen demand is exerted on the water (2). Nitrate nitrogen, one end product of aerobic stabilization, is undesirable in surface water supplies because of the relationship between high nitrate concentrations and infant methemaglobinemia (18). Instances also exist in which animal wastes may have been the source of excessive nitrate concentrations in ground water (16).

Another problem associated with feedlot runoff is the transmission of infectious disease organisms. The number of waterborne diseases which can be transmitted from animal to man probably exceeds fifty (19). Of these diseases, fifteen can be contracted orally (20). Nevertheless, the number of recorded cases are few. One case exists in which several young people swimming in the Cedar River in Iowa were infected with leptospirosis. Infected cattle which had access to an upstream portion of the river provided the source of infection (2). The human disease hazards of agricultural land drainage in the United States do not constitute a major health threat. However, agricultural land drainage may be labeled "unsafe" from a health standpoint (20).

Handling Feedlot Runoff

The actual water pollution attributable to feedlot wastes is dependent upon the discharge of feedlot runoff into a receiving body of water (2). The degree of pollution which will result depends not only upon the volume and concentration of runoff, but also upon the nature of the receiving stream. The length of time in which the runoff is discharged to the stream is also important (7).

A system designed for the purpose of handling feedlot runoff must be adapted to the specific characteristics of the runoff. An ideal system should be able to handle wide fluctuations in flow because runoff occurs on an intermittent basis and should be able to accommodate large quantities of organic and inert material. Furthermore, the system should be easy to operate, require little maintenance, and be economical (9).

In order to reduce the pollution potential of a feeding operation, the waste load leaving the feedlot by runoff should be minimized. There are a number of hydrological methods by which this may be accomplished. One system involves the construction of terraces on the feedlot surface. The terraces help retain the runoff and solids on the lot surface. A precaution to consider, however, is that an unfavorable environmental condition must not be created for the animals (3). Another technique which could be utilized in feedlot runoff control involves the diversion of all surrounding runoff from passing over the feedlot surface. Consequently, the volume of runoff from a feedlot is reduced (7). The volume of runoff may also be decreased by a reduction in feedlot area. For two feedlots with the same number of animals, the volume of runoff will probably be less from the feedlot with the high animal density.

As a result, in the determination of feedlot size, it is important to provide an optimum animal density (3).

The complete elimination of rain from a feedlot is another answer to the runoff problem. An example of an operation employing this technique is that of the Western Consumers Industries, Incorporated of Ontario, California. At this operation, 9,600 head of cattle were confined in a seven acre, roofed feedlot. The roofed feedlot completely eliminated rainfall from falling on the lot. The waste disposal problem was solved by dehydrating the manure and selling the dried manure as a soil conditioner (3).

Implementation of the various hydrological methods of runoff control generally will not eliminate all runoff from a feedlot. As a result, some additional control measures may be required. One system with considerable potential involves the installation of a retention pond which will store the runoff leaving a feedlot. After the solids are allowed to settle, the effluent can be handled in several ways. Possibilities include controlled release to a stream, to nearby cropland, or to a subsequent treatment system. Controlled release refers to the continuous discharge of retention pond effluent over an extended period of time. Controlled release to a stream may be satisfactory in some situations. Because the retention pond effluent is discharged over an extended period of time, the shock loading effect of the feedlot runoff in a stream is minimized (3). The retention pond effluent can be spread over nearby cropland through a sprinkler irrigation system. The liquid must be free of bedding or other solids which would obstruct the system (11). Another possible means of handling the retention pond effluent is by controlled release to a biological treatment system. Properly designed aerated lagoons and oxidation ponds could offer a substantial degree of biological treatment (3).

EXPERIMENTAL METHODS

The objective of this investigation was to determine the pollutional characteristics of the runoff from two different types of feedlots. The two units selected for the investigation were the Animal Nutrition unit which is operated by the Animal Science Department and the Dairy Research and Production Unit which is operated by the Dairy Science Department at South Dakota State University. Both units are located approximately one mile north of the city of Brookings along Highway 77 in the Six Mile Creek drainage basin of east-central South Dakota. Drainage from each unit must travel approximately one mile prior to discharge into the receiving waters of Six Mile Creek. Figure 1 is a schematic diagram of the research area. Figures 2 and 3 show aerial views of the two units.

The investigation was conducted at these units for several reasons. First of all, the location of the units made them readily accessible from Brookings. Secondly, at both units the runoff was discharged to a point; therefore, flow measurement was possible. Finally, each unit was considered to be reasonably typical of feeding conditions which occur in South Dakota.

Animal Nutrition Unit

The operation at the Animal Nutrition unit was associated with beef and sheep nutrition research. The beef confinement area

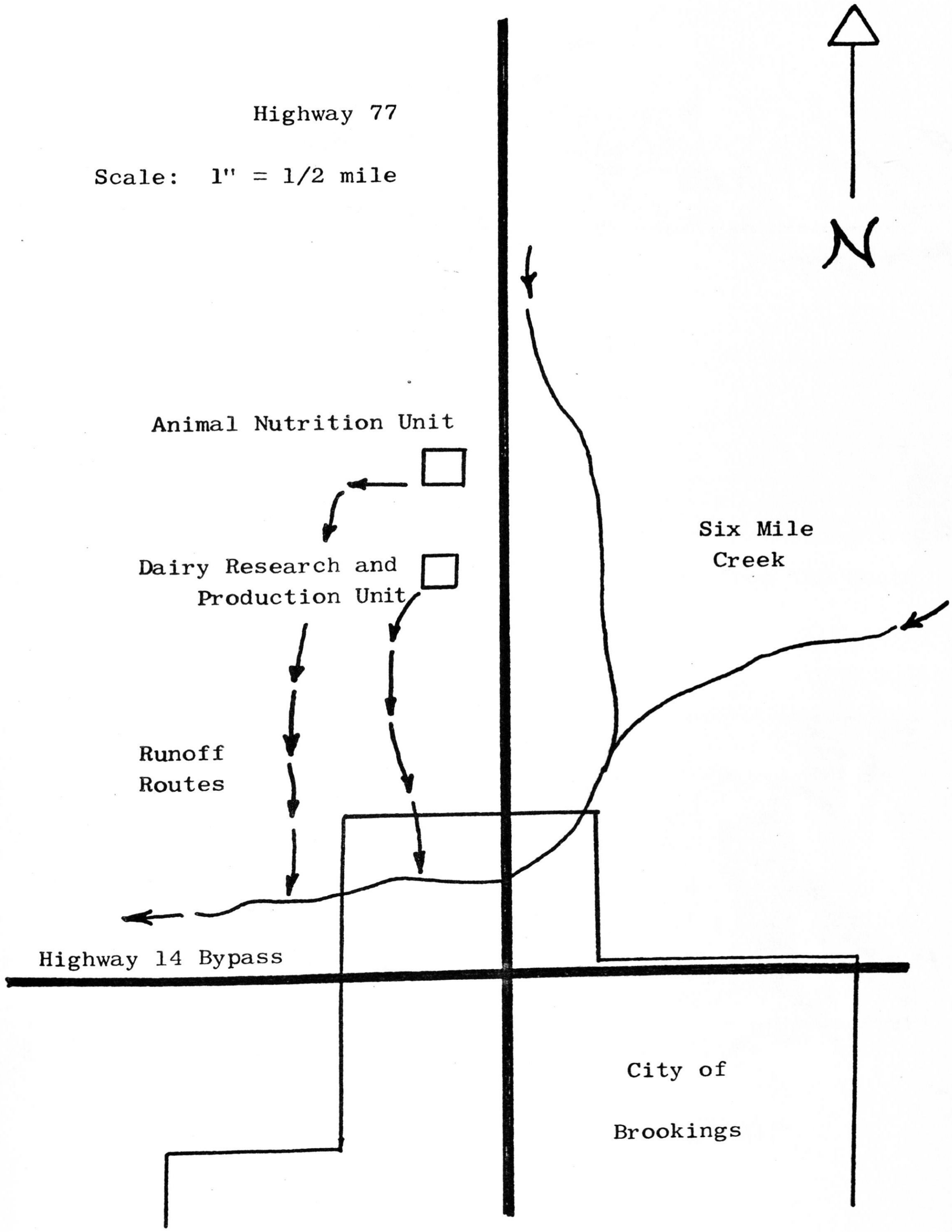

Figure 1. Schematic Diagram of Research Area.

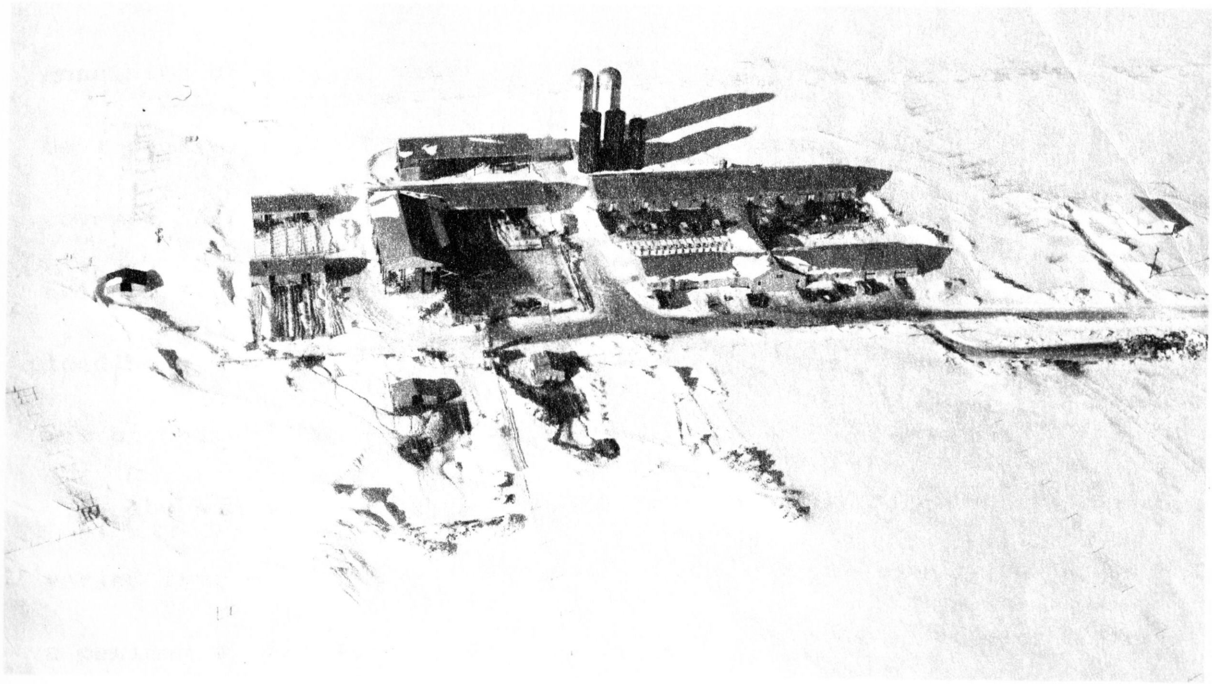

Figure 2. Dairy Research and Production Unit Viewed from the South.

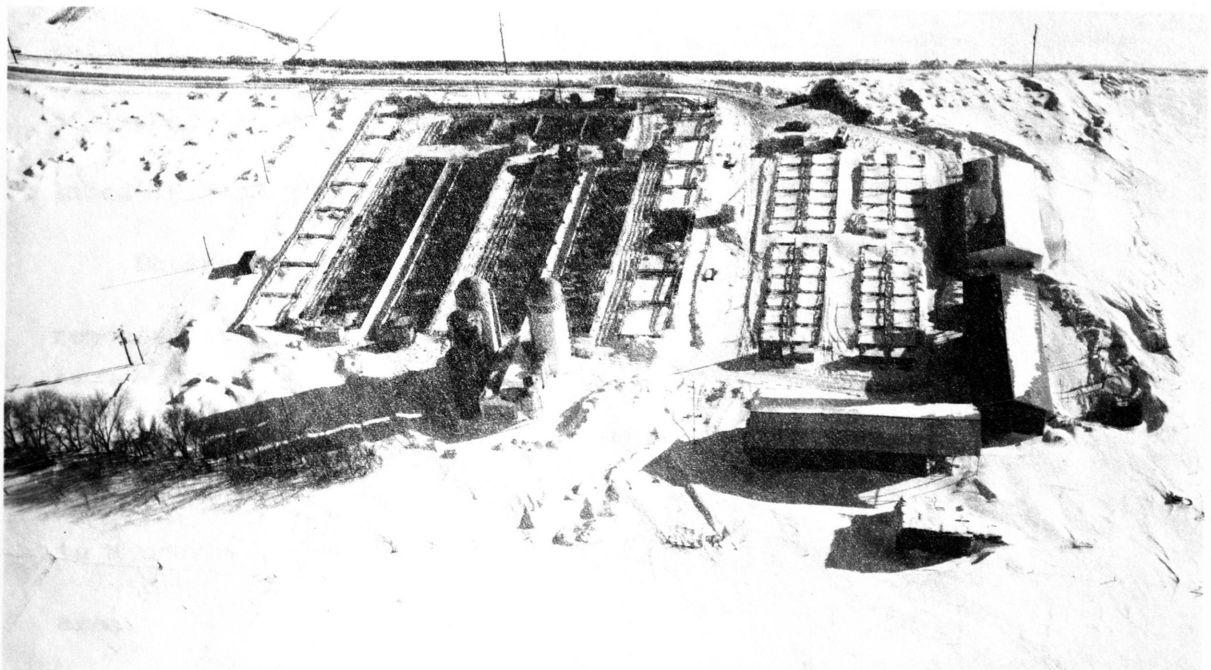

Figure 3. Animal Nutrition Unit Viewed from the North.

consisted of 52 pens which had a total pen area of 0.94 acres. The beef pens were located upon a rectangular concrete slab which covered an area of 1.49 acres. The concrete foundation had a uniform slope of two per cent to the south. A view of the beef feeding operation is shown in Figure 4. The sheep confinement unit was unsurfaced and consisted of 56 pens in a 0.29 acre area.

The number of livestock confined at the Animal Nutrition unit varied from only 210 head of cattle from January through April to a maximum of 478 head of cattle and approximately 700 sheep during June. Their diet consisted primarily of corn and various supplements. The cattle were generally in the 600-900 pound weight range, while the sheep weighed less than 100 pounds[1]. A complete record of livestock numbers from January 1 through June 30, 1969, is tabulated in Appendix 2.

During the winter, excessive snow accumulations were routinely removed from the beef pens. The snow was dumped only a short distance from the beef pens. The winter manure accumulation in the beef pens was removed during the latter part of April and was hauled to a nearby field which was not located within the same drainage area.

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[1]Interview with Dr. Lawrence Embry, Animal Science, South Dakota State University, May, 1969.

Figure 4. Beef Feeding Operation at the Animal Nutrition Unit.

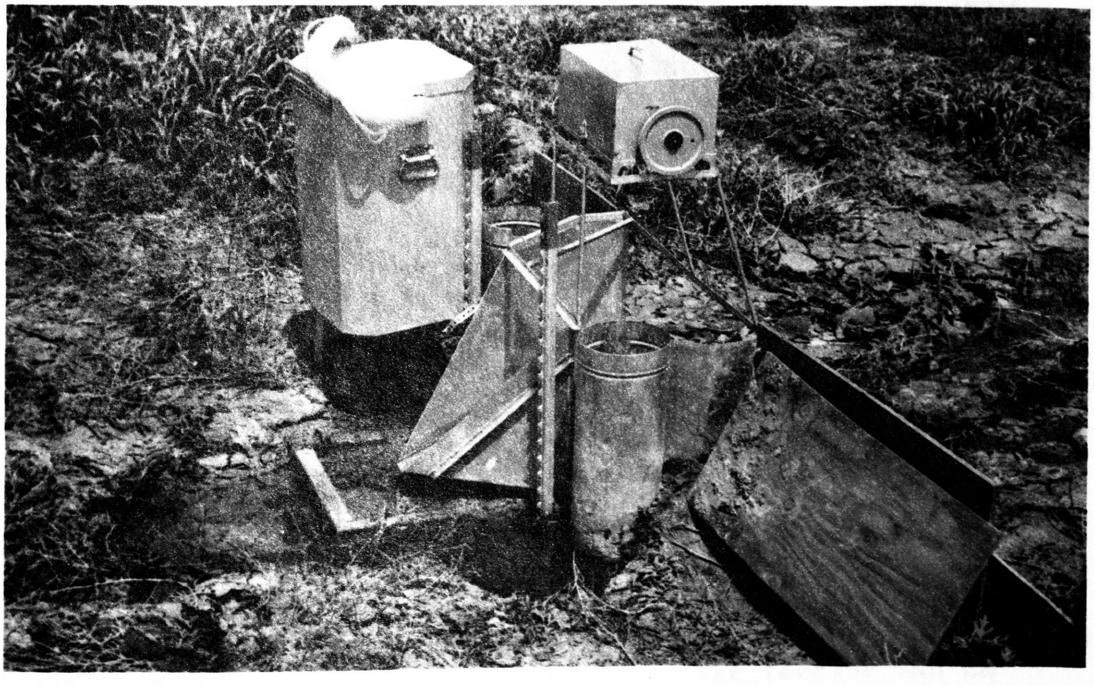

Figure 5. Type H Flume Installation at the Animal Nutrition Unit.

An 18-inch Type H flume was used for flow measurement at the Animal Nutrition unit. The flume had a maximum capacity of approximately 2400 gallons per minute (gpm). An automatic stage recorder which was mounted on the flume obtained a continuous water level reading as runoff passed through the flume. A calibration curve for the flume permitted the conversion from water level to discharge in gallons per minute.

The flume was located such that the drainage area which contributed runoff to the flume covered an area of approximately 8-1/4 acres. The 8-1/4 acres of drainage included 1.49 acres of beef cattle facilities, 0.29 acres of sheep pens, less than one acre of graveled driveways, and from five to six acres of brome grass and alfalfa. The flume installation is shown in Figure 5. The drainage patterns and the contributing drainage areas are shown in Figure 6.

Dairy Research and Production Unit

The feedlot which was investigated at the Dairy unit was a confinement area for dry cows and for heifers over 15 months of age. The area of the feedlot which was open to the atmosphere measured approximately 0.32 acres. The feedlot was unsurfaced and was bordered by a loafing barn located at the north end of the lot and by a hay shed along the west side of the lot. The feedlot had an average slope of approximately 3-3/4 per cent to the southwest. A

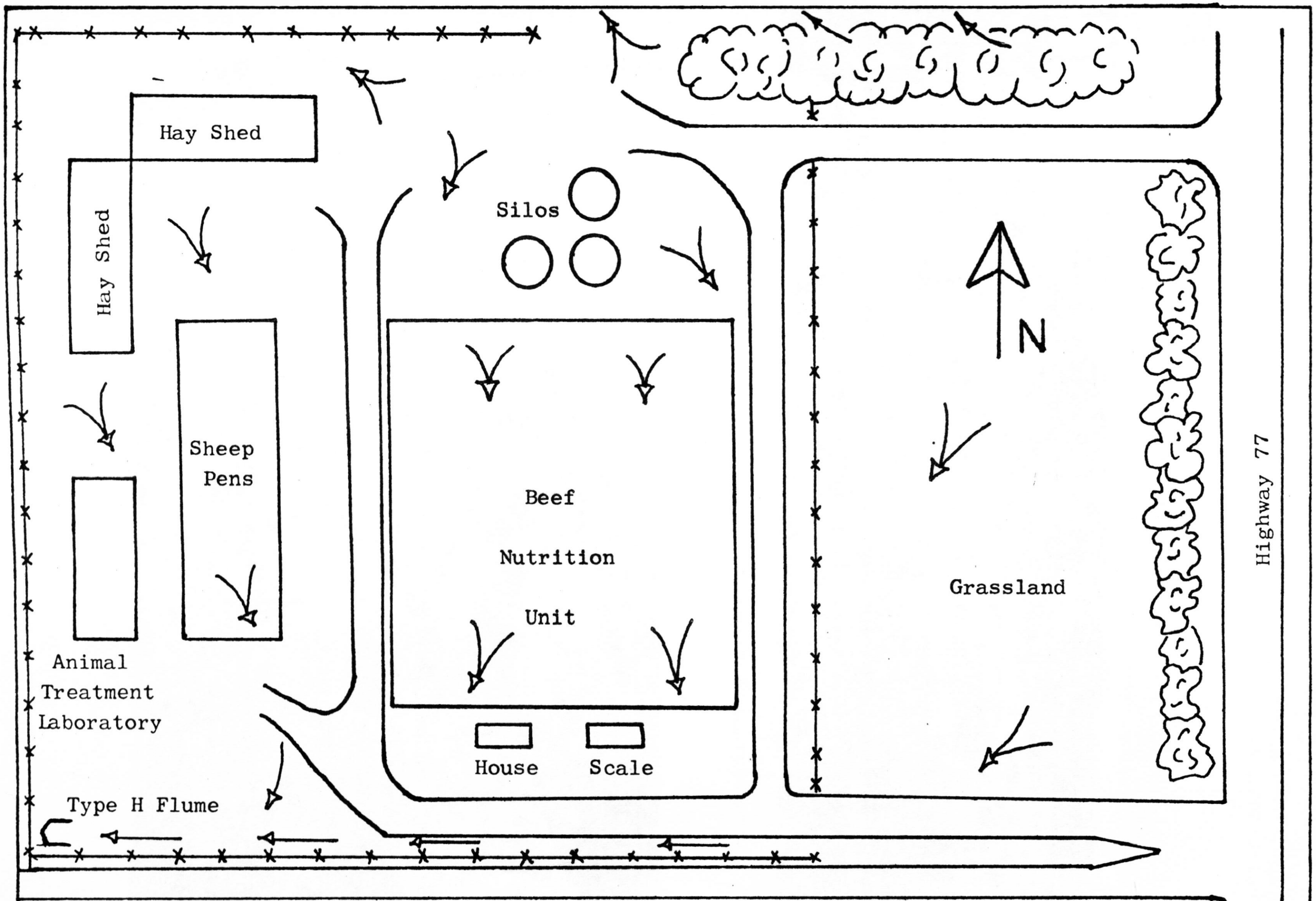

Figure 6. Drainage Patterns at the Animal Nutrition Unit. (not to scale)

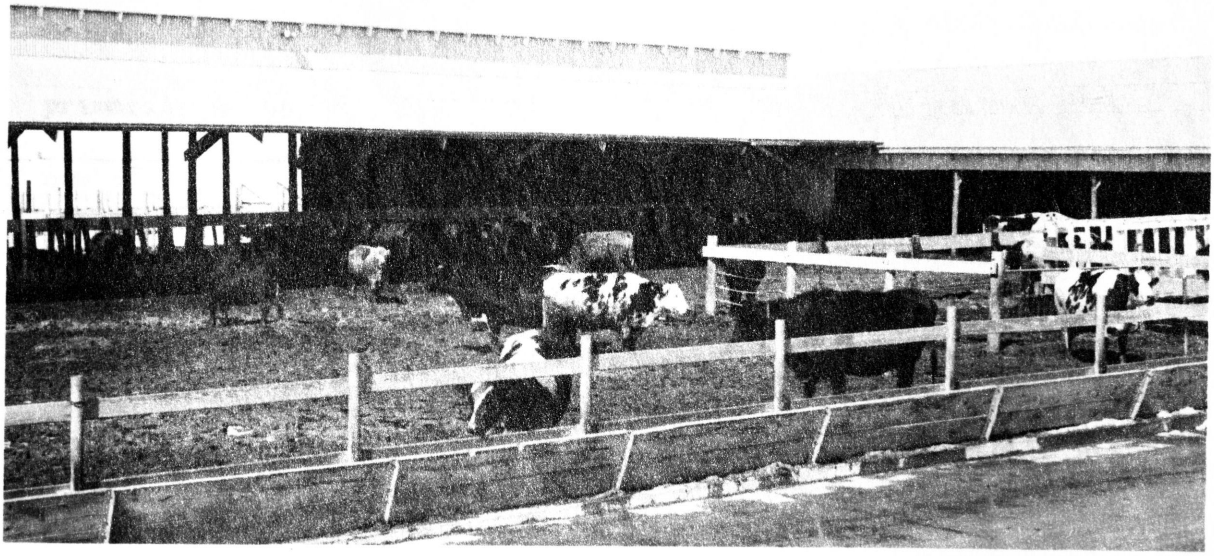

Figure 7. View of Confinement Area at the Dairy Research and Production Unit.

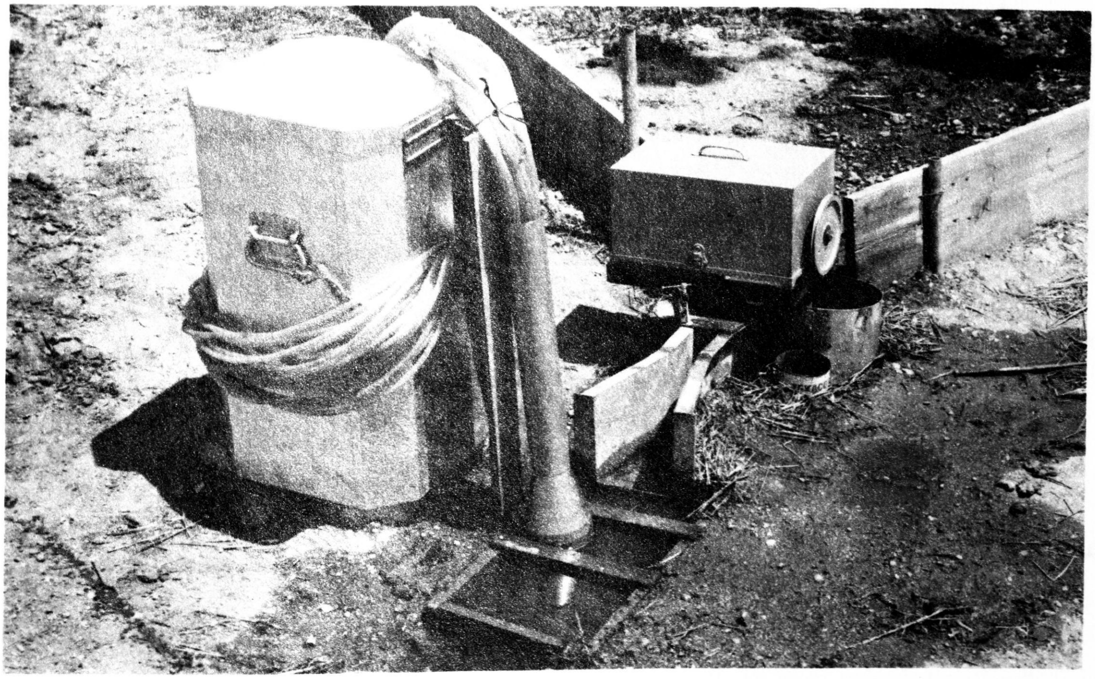

Figure 8. Parshall Flume Installation at the Dairy Research and Production Unit.

The main objective of the confinement area at the Dairy unit was to maintain the heifers and cows in optimum condition for calving. Because rapid weight gains were not necessary, their diet consisted primarily of hay and some silage. During the investigation, the number of cows and heifers confined on the lot generally varied from 40 to 50 head. The average animal weight was estimated at 1100 pounds[2].

Prior to the spring snowmelt, a large percentage of the snow accumulation was removed from the lot. As a result, the volume of snowmelt runoff from the feedlot was considerably reduced. The winter manure accumulation was removed during April and was spread on a nearby field.

A two-inch Parshall flume was used for flow measurement at the Dairy unit. Maximum capacity of the flume was approximately 100 gpm. An automatic stage recorder was installed to record a continuous water level reading for runoff passing through the flume. A calibration curve for the flume permitted the conversion from water level in the flume to discharge in gallons per minute.

The flume was installed at a location just outside the area confined within the feedlot. Because the contributing drainage area was limited to the area inside the feedlot, only a small amount of

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[2]Interview with Myers Owens, Herdsman at Dairy Research and Production Unit, South Dakota State University, May, 1969.

external drainage was measured. However, during several high intensity rains, the eave troughs on the loafing barn and hay shed were overloaded. The overflow was discharged onto the lot.

During several of the high intensity rains, the capacity of the flume was surpassed. Consequently, accurate flow data were not always obtained. The drainage area at the Dairy unit was approximately 0.32 acres. The flume installation is shown in Figure 8. The drainage patterns and the contributing drainage area are shown in Figure 9.

Sampling Technique

During the snowmelt runoff period, one grab sample was obtained from the runoff at each unit every 24 hours. The grab samples were collected at random times throughout the daylight hours. The assumption was made that the waste concentrations in the grab sample represented the average waste concentrations in the snowmelt runoff for the entire 24-hour period.

During periods of runoff from rain, a different sampling technique was used. Serco automatic samplers were used to obtain one sample every hour throughout the duration of the runoff period. Because the period of runoff resulting from some of the rains was very short, samples were, in some cases, obtained manually over time intervals ranging from 20 to 30 minutes. The runoff samples obtained during snowmelt and rainfall were collected at the discharge end of

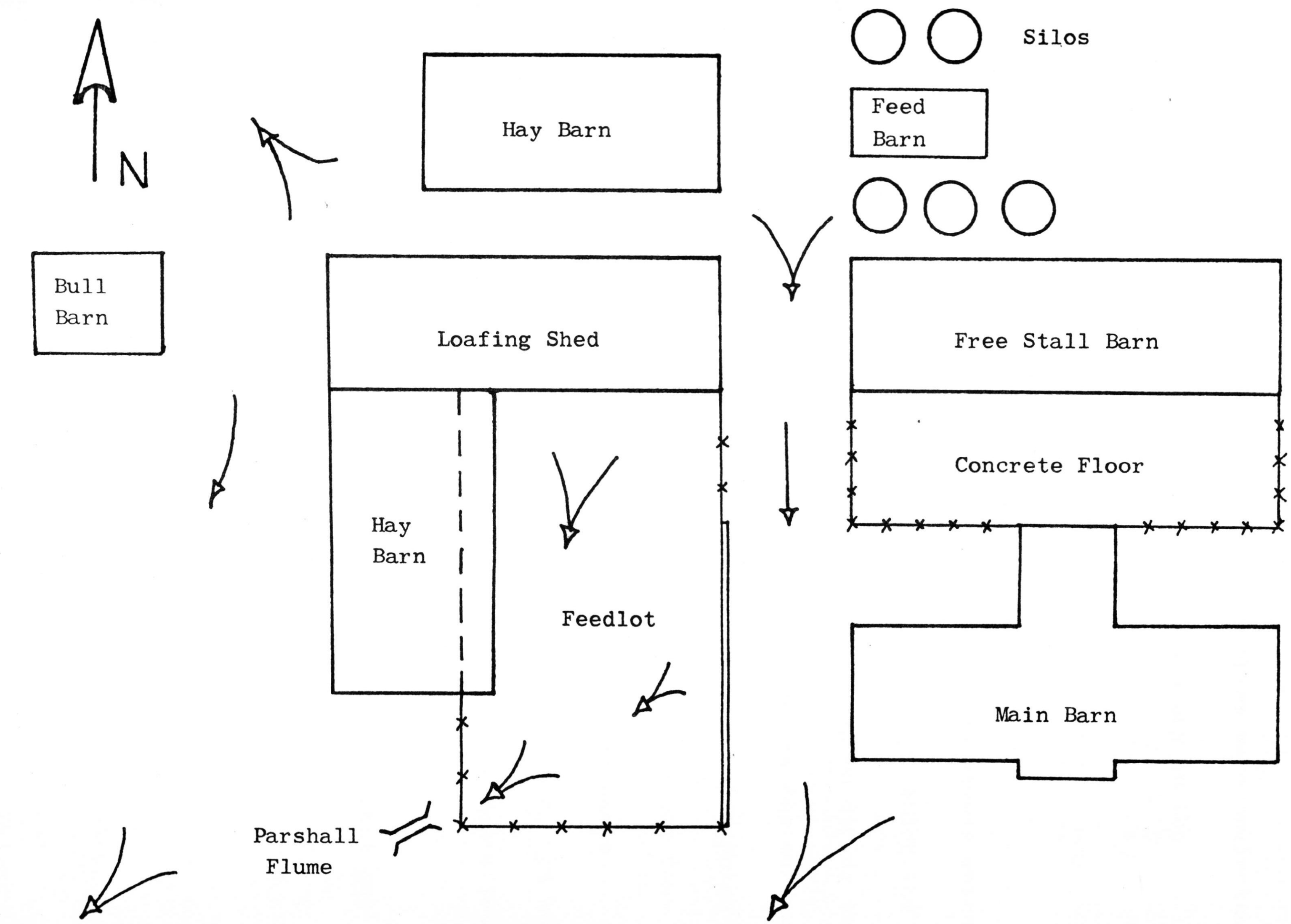

Figure 9. Drainage Patterns at the Dairy Research and Production Unit. (not to scale)

the flumes. Figures 5 and 8 show the position of the Serco automatic sampler at the two installations. After the samples were collected, they were refrigerated in the Water Quality Laboratory in the Agricultural Engineering building.

Compositing Technique

The purpose of compositing was to obtain a single sample which would be representative of the entire runoff period over which the individual grab samples were collected. Samples obtained during the period of spring snowmelt were composited by considering the average daily head as recorded by the stage recorder. In this way samples which were collected on days when the runoff volume was large constituted a greater portion of the composited sample than those samples which were collected when the runoff volume was low. In most cases the composited samples contained portions of four consecutive daily samples.

For grab samples obtained during rain runoff, a different compositing technique was used. These samples were composited to represent the instantaneous flow at the time of sampling.

Tests Performed

The pollutional characteristics of the feedlot runoff were measured by several parameters including the 5-day biochemical oxygen demand (BOD), chemical oxygen demand (COD), total solids, suspended solids, volatile suspended solids, Kjeldahl nitrogen, and total soluble phosphorus. The tests were performed on runoff samples collected from each unit from March 16 through June 30. The laboratory determinations were conducted in the Water Quality Laboratory on the South Dakota State University Campus.

All tests with the exception of the suspended solids analyses were performed as outlined in the twelfth edition of Standard Methods (21). Suspended solids and volatile suspended solids analyses were performed using glass fiber filters according to a procedure reported by Wyckoff (22).

The BOD test was selected because it measures the strength of the waste in terms of oxygen required for stabilization. BOD can be defined as "the amount of oxygen required for the biological decomposition of dissolved organic solids to occur under aerobic conditions and at a standardized time and temperature". The 5-day BOD measures the oxygen utilized in the oxidation of carbonaceous matter (23-345).

The COD test is another common means of measuring the pollutional strength of a waste water. In the COD test, the oxygen demand of both the biologically oxidizable and the biologically inert organic matter is measured. The short time required for analysis is the main advantage of this test (24-414).

The solids characteristics provide additional information in evaluating a wastewater. Total solids is a measure of both the dissolved and suspended solids. Suspended solids is an important parameter because, like BOD removal, suspended solids removal is essential to water pollution control (24-444). The volatile content of the suspended solids provides a measure of the amount of organic matter present in the suspended matter (24-442).

The Kjeldahl nitrogen determination measures the ammonia and organic forms of nitrogen in a waste water (24-428). Nitrogen data are significant in waste water analysis for several reasons. The nitrogen concentrations of feedlot runoff can be quite high since animal wastes contain appreciable amounts of organic nitrogen (24-421). In addition the oxidation of organic and ammonia nitrogen can exert an appreciable oxygen demand on receiving waters and may, therefore, affect dissolved oxygen concentrations in the water. Since nitrogen is essential to the life processes of all plants and animals, it is a major consideration in evaluating the productivity of natural waters (24-433). Instances exist in which the discharge of ammonia nitrogen into a receiving stream has resulted in fish kills. The fish kills in some instances did not result from an oxygen deficit, but rather from an extreme irritation of the flesh and gills of the fish (16).

Phosphorus data have become increasingly important in recent years in evaluating the potential biological productivity of a body of water (24-472). In terms of a water's productivity, phosphorus is often considered to be the most critical single factor (25). As a result, phosphorus determinations are essential in evaluating the effects of a wastewater being discharged into a receiving body of water. The analysis for total soluble phosphorus was performed in the investigation. The procedure measures the orthophosphates and polyphosphates dissolved in the water.

Suspended Solids Reduction by Centrifugation

By performing selected tests on raw and centrifuged samples, it was possible to determine the effect of suspended solids reduction on the waste concentrations. The raw and centrifuged samples consisted of composited samples from the two units which were studied. The centrifuged samples were prepared by centrifuging raw samples for 20 to 30 minutes at rates ranging from 3500 to 4000 rpm.

The length of time required for quiescent settling which would be equivalent to various centrifuging conditions was not investigated. As a result, it was not possible to relate the suspended solids reduction by centrifuging to that which would occur in a retention pond during a certain period of time.

RESULTS AND DISCUSSION

The investigation of the pollutional characteristics of the runoff from the Animal Nutrition unit and the Dairy Research and Production unit was conducted from March 1 through June 30, 1969. Feedlot runoff from snowmelt first occurred on March 16 at the Dairy unit. The three primary objectives of the investigation included the determination of the quantity and quality of feedlot runoff, the evaluation of runoff from spring snowmelt as well as from runoff-producing rains, and the determination of the changes in waste concentrations due to suspended solids reduction. During the discussion of the data, population equivalent relationships for the two feedlots were analyzed. An assessment was also made of the actual water pollution which could be attributed to the runoff from the two feedlots.

Precipitation and Runoff Relationships

Precipitation data which were used throughout the investigation were obtained from the Environmental Science Services Administration located on the campus of South Dakota State University. According to the precipitation records, a total of 72.5 inches of snow fell in the Brookings area during the winter of 1968-1969. From mid-March through June 30, a total of 11.5 inches of rain was recorded. The rainfall occurred on 34 separate dates and ranged from a maximum rainfall of

2.5 inches on June 22 to only a trace of rainfall on two occasions (26). Rainfall data are contained in Appendix I. Since both units are located approximately two miles from the official weather bureau station at Brookings, it was assumed that the precipitation which occurred at the two feedlots was substantially the same as the precipitation recorded at the Brookings station.

Animal Nutrition Unit. A representation of the spring precipitation and runoff data for the Animal Nutrition unit is shown in Figure 10. The actual precipitation and runoff data are recorded in Appendix I and II. During the period of investigation, a total of approximately 1,347,000 gallons of runoff were produced at this unit. This was equivalent to 6.0 inches of water evenly distributed over the entire 8-1/4 acre drainage area. Runoff from snowmelt accounted for 82 per cent of the total flow, while rainfall contributed only 18 per cent of the total runoff volume.

Runoff from snowmelt at this unit first occurred on April 1 and continued daily through April 22. The total volume of snowmelt runoff which passed through the Type H flume during this period of time was approximately 1,105,000 gallons. This volume was equivalent to 4.92 inches of water distributed over the 8-1/4 acre drainage area. It is doubtful, however, that the entire drainage area uniformly contributed the 4.92 inches of snowmelt runoff. The concrete floor at the beef pens probably contributed proportionately less snowmelt

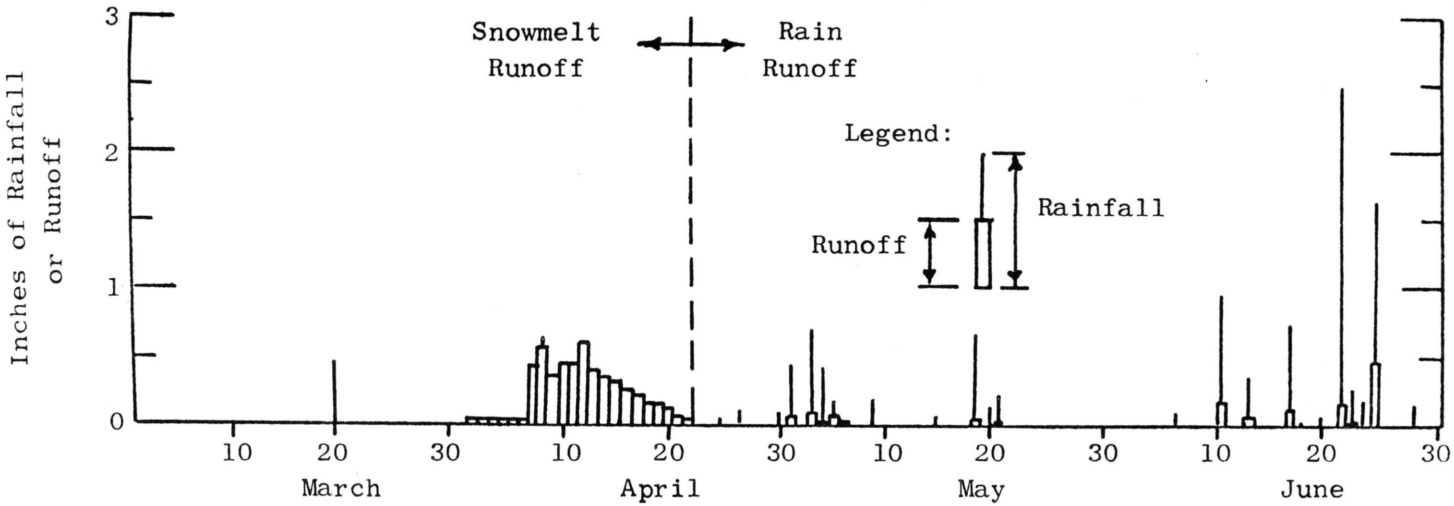

Figure 10. Rainfall and Runoff Data for Animal Nutrition Unit.

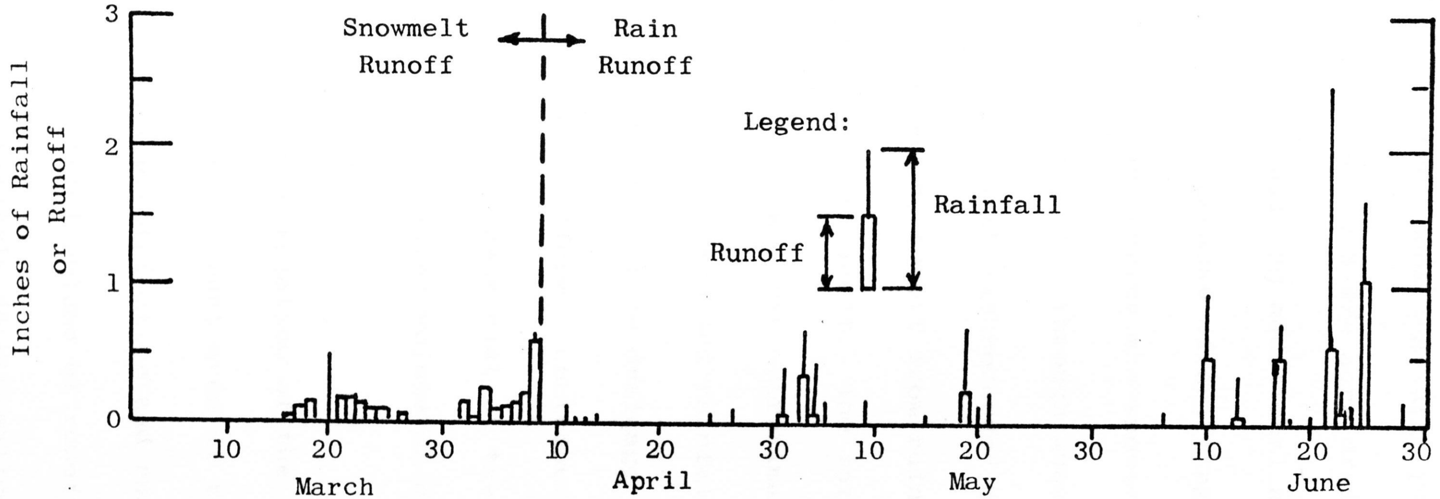

Figure 11. Rainfall and Runoff Data for the Dairy Research and Production Unit.

runoff than was contributed by the adjoining drainage area. This was due to the routine removal of snow from the beef pens. A large portion of the snow that was removed was stored within the 8-1/4 acre drainage area. In addition to the 72.5 inches of snowfall, an additional amount was accumulated on the adjoining drainage area because of drifting.

Rainfall was recorded on nine separate days during the snowmelt period and on 25 days from the completion of snowmelt through June 30. A daily rainfall accumulation in excess of one inch was recorded on only two days during the investigation. However, runoff from rainfall occurred on 13 days following the completion of snowmelt. The total volume of rain runoff from the Animal Nutrition unit was approximately 242,000 gallons. As a result, the 11.5 inches of recorded rainfall produced only 1.08 inches of rain runoff over the entire drainage area. It is unlikely that the 1.08 inches was uniformly contributed from the entire drainage area. The 1.49 acre concrete slab at the beef pens probably contributed a substantially greater volume of runoff than the vegetative areas in the drainage basin.

Dairy Research and Production Unit. A representation of the spring precipitation and runoff data for the confinement area at the Dairy unit is shown in Figure 11. The actual precipitation and runoff data are recorded in Appendix I and II. The total volume of runoff produced from snowmelt and rainfall was approximately 48,800 gallons. This would be equivalent to a runoff depth of 6.0 inches distributed evenly over the 1/3 acre feedlot area. Approximately 56 per cent of the total runoff volume was contributed by rain runoff. Runoff from snowmelt accounted for 44 per cent.

At this unit, runoff from snowmelt first occurred on March 16 and continued on an intermittent basis through April 8. The total volume of snowmelt which flowed from the confinement area was approximately 21,000 gallons. This would be equivalent to 2.59 inches of water over the feedlot area. Since the entire drainage area is enclosed within the boundary of the feedlot, flow was not contributed by adjacent drainage areas. The depth of snowmelt runoff was substantially lower than that at the Animal Nutrition unit because a large portion of the snow accumulation was removed from the Dairy feedlot prior to snowmelt. Consequently, the volume of snowmelt runoff was considerably reduced. At the Animal Nutrition unit, the snow which was removed from the beef pens was stored in the same drainage area. As a result, snow removal from the beef pens probably had little effect on the total volume of runoff from the entire drainage area.

At the dairy unit, rainfall was recorded on five separate days during the snowmelt period and on 29 days from the completion of snowmelt through June 30. After the completion of snowmelt, runoff from rain occurred on only ten days. The total volume of rain runoff was approximately 27,400 gallons or an average of 3.38 inches over the feedlot area. Eave troughs mounted on the hay shed and loafing barn prevented roof runoff from discharging onto the feedlot except during high intensity rains when the eave troughs overflowed.

When the amounts of rain runoff from the Animal Nutrition unit and the feedlot at the Dairy unit are compared, a considerable difference can be noted. A depth of 3.38 inches of runoff was recorded at the Dairy unit feedlot, while only 1.08 inches was recorded at the Animal Nutrition unit. The difference can probably be attributed to the five to six acres of vegetation at the Animal Nutrition unit. The runoff from the vegetative areas was probably very small. As a result, the average depth of runoff from the Animal Nutrition unit would also be reduced.

Based upon a period of record from 1893-1965, the average annual precipitation at Brookings has been 20.37 inches per year. During an average year, 51.5 per cent of the average annual precipitation has occurred during the first six months of the year (27). Because a large part of the annual precipitation occurs during the months of April, May, and June and because snowmelt generally occurs during the spring months, the volume of feedlot runoff will generally be high during this time of the year. On the other hand, with rainfall accumulations of less than a quarter of an inch, the amount of runoff would probably be negligible. Precipitation at Brookings during the first six months of 1969 was higher than normal; a total of 15.13

inches of precipitation was recorded. This was approximately 74 per cent of the average annual precipitation at Brookings.

Waste Concentrations in Feedlot Runoff

The mean concentrations of various wastes which were present in the runoff from the two feedlots are included in Table 4. The mean concentrations were computed from the total pounds of constituents which were present in the feedlot runoff during the snowmelt and rainfall periods. The data indicate that high concentrations of wastes may be present in feedlot runoff. For example, the mean 5-day BOD concentration in the snowmelt runoff from the confinement area at the Dairy unit was 1,810 mg/l.

An indication of the strength of feedlot runoff can be made by comparing it to the strength of domestic sewage. The concentration of 5-day BOD in a medium strength sewage is approximately 200 mg/l, while the total solids and Kjeldahl nitrogen concentrations are approximately 500 mg/l and 50 mg/l, respectively (23-341). In comparison, the concentrations of these parameters in the feedlot runoff were generally much higher than the domestic sewage concentrations.

The waste concentrations in the snowmelt runoff from the Animal Nutrition unit were quite low when compared to the concentrations observed in the rain runoff. During snowmelt the runoff leaving the beef pen area was probably significantly diluted by snowmelt runoff

Table 4. Summary of the Mean Concentrations and Unit Quantities of the Waste Characteristics of the Two Feedlots during the Snowmelt and Rainfall Periods.

		Snowmelt Runoff			Rainfall Runoff		
Parameter	Units	Animal Nutrition	Dairy Units	Average	Animal Nutrition	Dairy Units	Average
Feedlot Area	Acres	1.49	0.32	--	1.78	0.32	--
Runoff Volume	gallons	1,105,300	20,970	--	241,800	27,420	--
	inches	4.92*	2.59	3.75	1.08*	3.38	2.23
BOD	mg/l	110	1,810		925	575	
	lbs/acre	690	940	815	1,050	405	725
COD	mg/l	570	7,550		3,900	4,910	
	lbs/acre	3,495	4,125	3,810	4,430	3,500	3,865
Total Solids	mg/l	950	11,120		4,330	6,510	
	lbs/acre	5,900	6,060	5,980	4,910	4,655	4,780
Suspended Solids	mg/l	225	5,140		2,430	2,680	
	lbs/acre	1,385	2,810	2,095	2,760	1,905	2,330
Volatile Suspended	mg/l	120	2,040		1,450	910	
Solids	lbs/acre	745	1,125	935	1,645	640	1,140
Kjeldahl Nitrogen	mg/l	80	780		215	270	
	lbs/acre	480	440	460	245	190	220
Total Soluble	mg/l	205	280		900	430	
Phosphorus	lbs/acre	1,275	155	715	1,015	310	660

* - Distributed over the 8-1/4 acre drainage area.

from the adjoining drainage area before it reached the flow measurement station. During rain runoff the wastes leaving the beef pen area would also be diluted but to a much smaller extent. It is believed that abundant vegetative cover on the adjoining drainage area reduced the volume of rain runoff from this area.

Wastes Removed by Runoff Per Acre of Feedlot Area

The two feedlots may also be compared when the wastes removed by runoff are expressed on a "pounds per acre" basis. The pounds of waste removed per acre during snowmelt and rainfall are shown in Table 4. The area of the dairy confinement lot which contributed the wastes during snowmelt and rainfall was 0.32 acres. During snowmelt at the Animal Nutrition unit, the 1.49-acre slab at the beef feeding operation was assumed to have contributed the entire waste load. However, during rainfall at this unit, 1.78 acres of feedlot was assumed to have contributed the wastes. This area consisted of 1.49 acres of beef feeding facilities and 0.29 acres of sheep pens which were in operation at this time. In both cases, the amount of waste contributed by the remainder of the 8-1/4-acre drainage basin at the Animal Nutrition unit was assumed to be negligible.

The "pounds per acre" values for the two feedlots were averaged for the snowmelt and rainfall runoff periods. These values may provide a basis for estimating the total waste load to be expected from feedlots of any size during these periods of time. For example, it would be reasonable to predict that a one-acre feedlot would have contributed approximately 1500-1600 pounds of BOD during the months of March, April, May, and June. As a result, the average BOD load removed from a one-acre feedlot during this period of time was approximately 13 pounds of BOD per day. Based on an average value of 0.17 pounds of BOD per capita per day, the average daily load of BOD removed from a one-acre feedlot during this period of time would be equivalent to the daily waste production of 77 people.

Waste Reduction by Centrifugation

One objective of the investigation was to evaluate the effect of suspended solids reduction on the waste concentrations in the runoff. Since suspended solids removal is an important feature of a retention pond, an indication of the degree of waste reduction which could be obtained by settling should be known. In the investigation, suspended solids concentrations in the runoff were reduced by centrifugation. It was assumed that centrifugation of the samples would approximate the effect of solids settling in a retention system. The analyses were performed on approximately fifteen raw and centrifuged samples from each unit in order to determine the reduction in waste concentration. The data are tabulated in Appendix IV.

The mean per cent reductions of 5-day BOD, COD, total solids, suspended solids, and Kjeldahl nitrogen are shown in Table 5. The mean reduction in suspended solids by centrifugation was 85 per cent at the Dairy unit and 78 per cent at the Animal Nutrition unit. Suspended solids reduction prompted the reduction of concentrations of other parameters. A maximum reduction of 28 per cent was obtained in the 5-day BOD at the Animal Nutrition unit. The smallest reduction was in Kjeldahl nitrogen at the Animal Nutrition unit; a reduction of 17 per cent was obtained.

By allowing suspended solids to settle, the concentrations of wastes in feedlot runoff may be partially reduced. Consequently, it would appear that a retention pond has potential in reducing waste concentrations by permitting the suspended solids to settle.

Table 5. Reduction in Waste Concentrations Accomplished by Centrifugation of Samples from Two Feedlots.

Determination	Per Cent Reduction at Dairy Unit	Per Cent Reduction at Animal Nutrition Unit
BOD_5	26	28
COD	24	23
Kjeldahl Nitrogen	21	17
Total Solids	27	25
Suspended Solids	85	78

Population Equivalent

Population equivalent is a term which attempts to establish a basis for comparing various industrial wastes with domestic wastes. The term is often reported with respect to the amount of wastes produced by animals. It is misleading to attempt to establish the actual pollution of a stream by estimating the quantity of animal wastes which are produced on a feedlot. The animal wastes must be transferred from a feedlot into a receiving body of water before water pollution can occur (8).

The population equivalent relationships for the two units are presented in Figures 12 and 13. Calculations of population equivalent were based upon 5-day BOD values published by Taiganides (1) and Lipper (21). It was assumed that a 1000-pound dairy or beef animal produced wastes on a BOD basis which was equivalent to the waste production of ten people. A population equivalent of one person was assumed for sheep weighing from 75 to 100 pounds. According to Figure 12, there was only one day from January 1 through June 30 at the Animal Nutrition unit in which the population equivalent of the waste in the runoff exceeded the population equivalent of the waste produced on the feedlot. This occurred during a high-intensity rain on June 25. From January 1 through June 30, the average daily waste production at the Animal Nutrition unit could be construed to be equivalent to the daily waste production of 2,120 people. However,

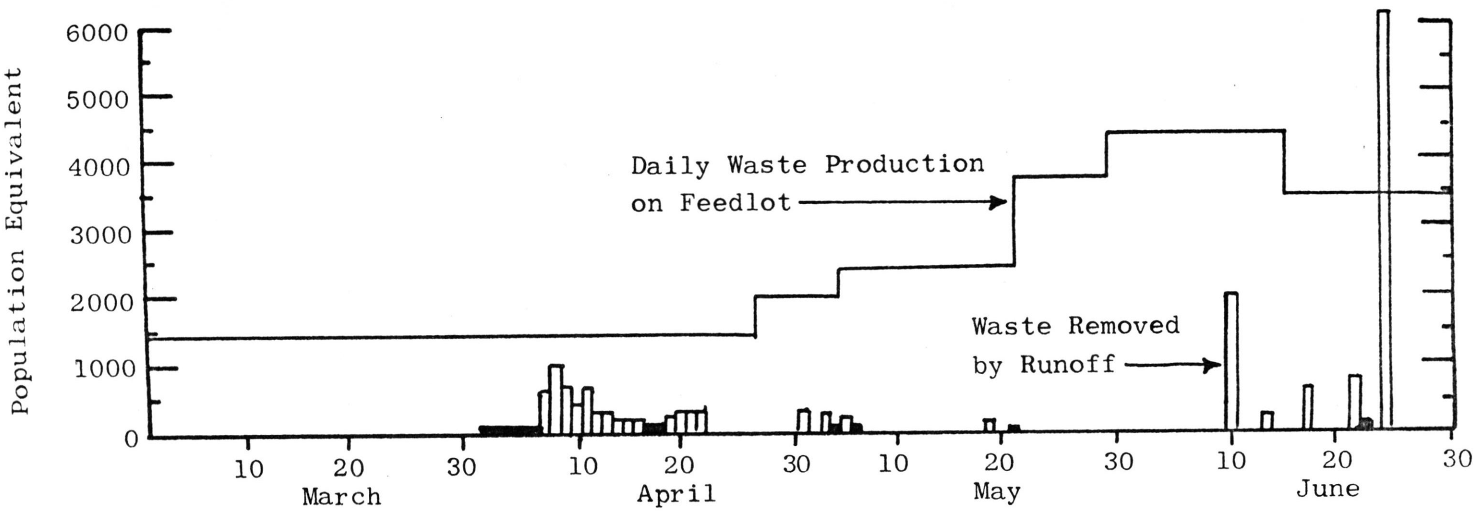

Figure 12. Population Equivalent Relationships for Animal Nutrition Unit.

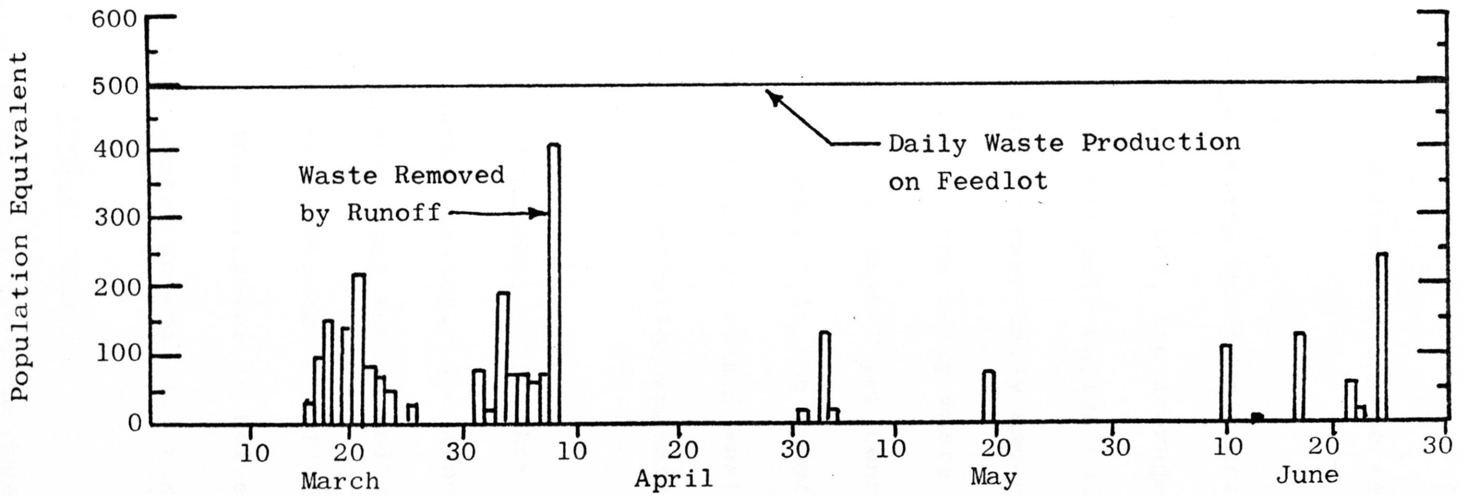

Figure 13. Population Equivalent Relationships for the Dairy Research and Production Unit.

the average daily amount of wastes removed in the runoff was equivalent to the daily waste production of only 94 people. Consequently, less than five per cent of the total waste load produced on the feedlot was removed by runoff.

The population equivalent relationships at the Dairy unit are shown in Figure 13. For the first six months of 1969, the average daily waste production on the feedlot was approximately equivalent to the daily waste production of 495 people. The average daily amount of wastes removed in the runoff was equivalent to the daily waste production of only 14.5 people. As a result, less than 3 per cent of the total waste produced on the dairy lot was removed in the runoff. It becomes quite obvious then that the total amount of animal waste produced was a poor representation of the actual pollution emanating from the feedlots.

The validity of the population equivalent concept is further questioned because of the treatability of animal wastes. The manure from animal sources is quite different from municipal sewage solids in that the animal manure is typically high in lignaceous and fibrous organic matter (6). As a result, the 5-day BOD parameter is not especially appropriate in comparing livestock wastes to domestic wastes.

Evaluation of Pollution Resulting from the Feedlot Runoff

The actual pollution which occurred in Six Mile Creek because of the runoff from the units was not determined by stream sampling.

However, an indication of the degree of degradation which may have occurred during this investigation can be discussed.

Until the feedlot runoff actually enters a receiving body of water, water pollution may not occur. During the period of spring snowmelt, it is quite likely that a portion of the feedlot runoff entered Six Mile Creek. The pollutional effects, however, were probably negligible because of flood waters that were present. A peak flow of 33,900 cfs was recorded in the Big Sioux River at the Brookings Station on April 9, 1969[3].

Feedlot runoff resulting from rain occurred on numerous occasions. If the feedlots had been located on the banks of Six Mile Creek, some degradation may have resulted. However, the feedlots were located approximately one mile from the creek. The topography of the area was such that movement of runoff through the area was quite restricted during the growing season. Throughout the entire spring rainfall period, runoff from the Animal Nutrition unit was observed on only two occasions at a point approximately one-half mile from the feedlot. These two instances occurred on June 22 and 26. During the other rain-runoff periods, the feedlot runoff percolated into the ground before it traveled the half-mile distance. Because the distance from the feedlots to the receiving waters of

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[3]Private communication with Vern Butler, Engineer Manager, East Dakota Conservancy Subdistrict, Brookings, South Dakota.

Six Mile Creek was approximately one mile, the probability of rain runoff entering Six Mile Creek from the feedlots was quite small.

It is believed that proper land management may be beneficial in reducing the pollution from feedlot runoff. A method of handling feedlot runoff which could be implemented in some situations would involve the diversion of feedlot runoff onto cropland. Terraces could be constructed which would retain a portion of the feedlot runoff. Such a technique would permit sedimentation of solids and promote the percolation of water into the ground. Maintenance of grassed waterways is another technique which may be beneficial in feedlot runoff control. In addition, if drainage from nearby agricultural land is minimized, the possibility of feedlot runoff reaching a receiving stream may be reduced.

SUMMARY AND CONCLUSIONS

Analysis of the data obtained during the investigation led to the following conclusions:

1. Throughout the period of investigation, high concentrations of total and suspended solids, nitrogen, phosphorus, and oxygen-demanding material were present in the feedlot runoff.

2. Approximately six inches of runoff were produced at each unit from snowmelt and rainfall during the entire period of investigation. The snow removal operation in the beef pens and the dairy confinement lot reduced the volume of snowmelt runoff from these areas.

3. Population equivalent values of the total animal waste load produced on the two feedlots were not a valid assessment of the actual pollution attributable to the runoff from these units. Feedlot runoff removed less than five per cent of the population equivalent of the wastes produced at the Animal Nutrition unit from January 1 through June 30, while less than three per cent of the population equivalent of the wastes produced in the confinement area at the Dairy unit were removed by runoff during this period of time.

4. The water pollution resulting from the feedlot runoff from the two units was probably negligible during this investigation. During snowmelt the feedlot runoff was greatly diluted before it reached Six Mile Creek, while during the growing season, the feedlot runoff probably did not reach the receiving water of Six Mile Creek.

5. The centrifuging procedure was effective in reducing the waste concentrations of the runoff samples. Consequently, quiescent settling of feedlot runoff may provide some reduction in waste concentrations.

6. Diversion of feedlot runoff onto cropland may be a satisfactory means of handling feedlot runoff in some situations. Proper land management practices may also be beneficial in preventing feedlot runoff from entering a receiving stream. Maintenance of grassed waterways and reduction of runoff from cropland may be excellent techniques.

AREAS FOR FUTURE STUDY

1. Further studies should be conducted in order to obtain a better assessment of the animal waste problem. Bacteriological analyses of feedlot runoff could provide information pertaining to the health hazards associated with feedlot runoff.

2. An investigation of the waste concentrations in runoff from agricultural lands could be studied. This information would be beneficial in evaluating the nutrient loss from cropland and the effect which the runoff would have on a receiving body of water.

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APPENDIX I

Rainfall Data

Daily Rainfall Data for the Brookings Station from March 1 through June 30, 1969 (26).

Day of Record*	March Rainfall (inches)	April Rainfall (inches)	May Rainfall (inches)	June Rainfall (inches)
1			.10	
2		T	.41	
3				
4			.68	
5			.41	
6				
7				.10
8		.05		
9		.61		
10			.18	
11				.97
12		.11		
13		.03		
14		.01		.39
15		.05		
16			.05	
17				
18				.73
19			.25	.02
20	.48		.43	
21			.13	.06
22			.21	2.50
23				.28
24				.17
25				.35
26		.06		1.28
27	T			
28		.10		
29				.15
30				
31				

*Based on days from 7 AM the previous day to 7 AM on the day of record.

APPENDIX II

Runoff Data

Daily Runoff Data for the Animal Nutrition Unit
from April 1 through June 30, 1969.

Day of Record	April Runoff (Inches)*	May Runoff (Inches)*	June Runoff (Inches)*
1	T	0.02	
2	T		
3	0.01	0.07	
4	0.01	T	
5	0.01	0.02	
6	0.02	T	
7	0.43		
8	0.59		
9	0.36		
10	0.44		0.18
11	0.45		
12	0.60		
13	0.40		0.03
14	0.37		
15	0.32		
16	0.26		
17	0.21		0.12
18	0.12		
19	0.14	0.01	
20	0.12		
21	0.05	0.01	
22	0.02		0.14
23			0.01
24			
25			0.46
26			
27			
28			
29			
30			
31			

* The average depth of water distributed over the 8-1/4 acre drainage basin.

Daily Runoff Data for the Dairy Research and Production Unit from March 1 through June 30, 1969.

Day of Record	March Runoff (Inches)*	April Runoff (Inches)*	May Runoff (Inches)*	June Runoff (Inches)*
1		0.14	0.05	
2		0.02		
3		0.26	0.33	
4		0.10	0.05	
5		0.11		
6		0.14		
7		0.20		
8		0.57		
9				
10				0.49
11				
12				
13				0.02
14				
15				
16	0.06			
17	0.12			0.49
18	0.15			
19			0.21	
20				
21	0.18			
22	0.19			0.58
23	0.13			0.09
24	0.09			
25	0.08			1.06
26				
27	0.04			
28				
29				
30				
31				

* The average depth of water distributed over the 0.32 acre feedlot.

APPENDIX III

Number of Animals

at the Nutrition Unit

Livestock Numbers at Animal Nutrition Unit
from January 1 through June 30, 1969.[4]

Time Period	Number of Beef Cattle	Number of Sheep
January 1 - April 27	210	0
April 28 - May 4	282	0
May 5 - May 21	350	0
May 22 - May 29	478	0
May 30 - June 4	478	540
June 5 - June 15	478	729
June 16 - June 30	350	694

[4]Interview with Dr. Lawrence Embry, Animal Science, South Dakota State University, July, 1969.

APPENDIX IV

Analyses of Composited Runoff Samples and Concentration Reduction by Centrifugation

BOD Concentration of Composited Samples from the Animal Nutrition Unit and Per Cent Reduction by Centrifugation.

Composite Sample	Raw BOD (mg/l)	Centrifuged BOD (mg/l)	Per Cent Reduction
April 1-4	290	250	14
April 8-10	110	85	23
April 11-14	50	20	60
April 15-18	60	45	25
April 19-22	375	345	8
May 19, 7-10 AM	1615	1250	24
May 19, 10-12 AM	800	750	6
May 19, 12-2 PM	1220	950	22
June 10, 7-9 PM	1000	660	34
June 10, 9-10 PM	950	650	32
June 10-11, 10 PM-4 AM	670	450	33
June 13-14	800	630	21
June 17-18	460	250	46
June 22	520	430	17
June 23	860	740	14
June 25, AM	2300	1010	56
June 25, PM	900	580	36

Mean BOD Reduction = 28%

COD Concentration of Composited Samples from the Animal Nutrition Unit and Per Cent Reduction by Centrifugation.

Composite Sample	Raw COD (mg/l)	Centrifuged COD (mg/l)	Per Cent Reduction
April 1-4	370	1230	-41
April 8-10	680	410	40
April 11-14	190	190	0
April 15-18	330	300	9
April 19-22	680	680	0
May 19, 7-10 AM	6080	3680	39
May 19, 10-12 AM	3040	3550	-17
May 19, 12-2 PM	3920	2400	39
June 10, 7-9 PM	3530	4040	-14
June 10, 9-10 PM	3540	2890	18
June 10-11, 10 PM-4 AM	5620	1610	71
June 13-14	2860	1880	34
June 17-18	2100	1050	50
June 22	2540	1520	40
June 23	3750	2350	37
June 25, AM	7750	4790	38
June 25, PM	4520	2450	46

Mean COD Reduction = 23%

Total Solids Concentration of Composited Samples from the Animal Nutrition Unit and Per Cent Reduction by Centrifugation.

Composite Sample	Raw Total Solids (mg/l)	Centrifuged Total Solids (mg/l)	Per Cent Reduction
April 1-4	2160	1920	11
April 8-10	1275	905	29
April 11-14	665	590	11
April 15-18	545	530	3
April 19-22	1680	1675	0
May 19, 7-10 AM	4350	2985	31
May 19, 10-12 AM	2430	2045	16
May 19, 12-2 PM	3080	2830	8
June 10, 7-9 PM	4060	2770	32
June 10, 9-10 PM	3254	2590	20
June 10-11, 10 PM-4 AM	2440	2040	16
June 13-14	3570	2440	32
June 17-18	3050	1370	55
June 22	2800	1540	45
June 23	4020	2950	27
June 25, AM	7490	4310	42
June 25, PM	5270	2360	55

Mean Total Solids Reduction = 25%

Kjeldahl Nitrogen Concentration of Composited Samples from the Animal Nutrition Unit and Per Cent Reduction by Centrifugation.

Composite Sample	Raw Kjeldahl Nitrogen (mg/l)	Centrifuged Kjeldahl Nitrogen (mg/l)	Per Cent Reduction
April 1-4	230	200	13
April 8-10	95	90	5
April 11-14	60	55	8
April 15-18	45	40	11
April 19-22	175	160	9
May 19, 7-10 AM	220	165	25
May 19, 10-12 AM	195	165	15
May 19, 12-2 PM	130	165	-27
June 10, 7-9 PM	210	165	21
June 10, 9-10 PM	200	160	20
June 10-11, 10 PM-4 AM	125	110	12
June 13-14	150	110	27
June 17-18	105	75	29
June 22	135	100	26
June 23	195	155	21
June 25, AM	410	280	32
June 25, PM	225	125	44

Mean Kjeldahl Nitrogen Reduction = 17%

Suspended Solids Concentration of Composited Samples from the Animal Nutrition Unit and Per Cent Reduction by Centrifugation.

Composite Sample	Raw Suspended Solids (mg/l)	Centrifuged Suspended Solids (mg/l)	Per Cent Reduction
April 1-4	280	-	-
April 8-10	445	100	88
April 11-14	120	30	75
April 15-18	120	40	67
April 19-22	185	170	8
May 19, 7-10 AM	1970	385	80
May 19, 10-12 AM	720	275	62
May 19, 12-2 PM	700	380	46
June 10, 7-9 PM	1630	60	94
June 10, 9-10 PM	830	90	89
June 10-11, 10 PM-4 AM	1090	70	94
June 13-14	1510	90	94
June 17-18	1860	110	94
June 22	1820	220	88
June 23	1530	450	71
June 25, AM	4740	190	96
June 25, PM	3560	120	97

Mean Suspended Solids Reduction = 78%

BOD Concentration of Composited Samples from the Dairy Unit and Per Cent Reduction by Centrifugation.

Composite Sample	Raw BOD (mg/l)	Centrifuged BOD (mg/l)	Per Cent Reduction
March 16-18	2300	2000	13
March 21-24	1800	1650	8
April 1-8	1300	1100	15
May 19, 7-9 AM	550	440	20
May 19, 9-11 AM	950	800	16
May 19, 11 AM-2 PM	1060	860	19
June 10, 7-8 PM	580	500	14
June 10, 8-9 PM	540	450	17
June 10, 9-12 PM	600	570	5
June 13	440	280	36
June 17	600	380	37
June 22	240	200	17
June 23	440	300	22
June 25, AM	685	200	71
June 25, PM	370	80	78

Mean BOD Reduction = 26%

COD Concentration of Composited Samples from the Dairy Unit and Per Cent Reduction by Centrifugation.

Composite Sample	Raw COD (mg/l)	Centrifuged COD (mg/l)	Per Cent Reduction
March 16-18	7650	6350	17
March 21-24	7300	6050	17
April 1-8	6650	5400	19
May 19, 7-9 AM	3750	2850	24
May 19, 9-11 AM	6250	6000	4
May 19, 11 AM-2 PM	6750	6250	7
June 10, 7-8 PM	3550	2900	18
June 10, 8-9 PM	2850	2750	4
June 10, 9-12 PM	3850	3150	18
June 14	4600	4300	6
June 17	3600	2900	19
June 22	3550	3400	4
June 23	2950	1500	49
June 25, AM	7700	2050	73
June 25, PM	5350	900	83

Mean COD Reduction = 24%

Total Solids Concentration of Composited Samples from the Dairy Unit and Per Cent Reduction by Centrifugation.

Composite Sample	Raw Total Solids (mg/l)	Centrifuged Total Solid (mg/l)	Per Cent Reduction
March 16-18	9000	6970	22
March 21-24	11690	8010	32
April 1-8	10300	6550	36
May 19, 7-9 AM	3830	3120	19
May 19, 9-11 AM	7490	6420	14
May 19, 11 AM-2 PM	8140	7480	8
June 10, 7-8 PM	4710	3960	16
June 10, 8-9 PM	4250	3530	17
June 10, 9-12 PM	4700	4500	4
June 14	8020	6880	14
June 17	6340	4340	32
June 22	5120	2840	45
June 23	6160	5150	16
June 25, AM	5870	2860	51
June 25, PM	8590	1430	83

Mean Total Solids Reduction = 27%

Kjeldahl Nitrogen Concentration of Composited Samples from the Dairy Unit and Per Cent Reduction by Centrifugation.

Composite Sample	Raw Kjeldahl Nitrogen (mg/l)	Centrifuged Kjeldahl Nitrogen (mg/l)	Per Cent Reduction
March 16-18	860	825	4
March 21-24	950	965	- 1
April 1-8	740	645	13
May 19, 7-9 AM	155	140	10
May 19, 9-11 AM	325	280	14
May 19, 11 AM-2 PM	320	300	6
June 10, 7-8 PM	170	140	18
June 10, 8-9 PM	150	140	7
June 10, 9-12 PM	170	140	18
June 14	250	225	10
June 17	180	140	22
June 22	125	85	32
June 23	195	170	13
June 25, AM	340	100	71
June 25, PM	180	40	78

Mean Kjeldahl Nitrogen Reduction = 21%

Suspended Solids Concentration of Composited Samples from the Dairy Unit and Per Cent Reduction by Centrifugation.

Composite Samples	Raw Suspended Solids (mg/l)	Centrifuged Suspended Solids (mg/l)	Per Cent Reduction
March 16-18	2200	440	80
March 21-24	5420	-	-
April 1-8	5220	-	-
May 19, 7-9 AM	920	195	79
May 19, 9-11 AM	1560	330	79
May 19, 11 AM-2 PM	1210	355	71
June 10, 7-8 PM	815	75	91
June 10, 8-9 PM	950	65	93
June 10, 9-12 PM	3335	55	85
June 14	1450	35	98
June 17	2280	65	97
June 22	2250	150	93
June 23	1590	250	84
June 25, AM	1370	650	53
June 25, PM	7325	250	97

Mean Suspended Solids Reduction = 85%